

## Research Note

# 6-meter telescope observations of three dwarf spheroidal galaxies with very low surface brightness

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### ABSTRACT

Dwarf spheroidal galaxies (dSphs) are mostly investigated in the Local Group. DSphs are difficult targets for observations because of their small size and very low surface brightness. Here we measure spectroscopic and photometric parameters of three candidates for isolated dSphs, KKH 65=BTS23, KK 180, and KK 227, outside the Local Group. The galaxies are found to be of low metallicity and low velocity dispersion. They are among the lowest surface brightness objects in the Local Universe. According to the measured radial velocities, metallicities, and structural and photometric parameters, KKH 65 and KK 227 are representatives of the ultra-diffuse quenched galaxies. KKH 65 and KK 227 belong to the outer parts of the groups NGC3414 and NGC5371, respectively. KK 180 is located in the Virgo cluster infall region.

**Key words.** galaxies: dwarf – galaxies: distances and redshifts – galaxies: fundamental parameters – galaxies: photometry

## 1. Introduction

Karachentseva et al. (2010) selected nine candidates for isolated dSphs in the Local Supercluster. Here we study three galaxies (Table 1) from this list. KKH 65=BTS 23 was discovered by Binggeli et al. (1990) and rediscovered in radio observations by Karachentsev et al. (2001a). KK 180 and KK 227 were first found by Karachentseva & Karachentsev (1998).

As distinct from dwarf irregulars, dSphs tend to be close companions of bright giant galaxies. Many theoretical models explain the formation of early-type dwarf galaxies by interaction of their progenitors with massive neighbors and subsequent loss of gas (e.g., Einasto et al. (1974); Del Popolo (2012) and references therein). Isolated early-type dwarf galaxies are extremely rare within 10 Mpc (Karachentsev et al. 2001b; Makarov et al. 2012; Karachentsev et al. 2015). Their formation mechanism is still poorly understood. Their observational properties are of particular interest. Isolated dSphs were not able to interact with massive neighbors during their lifetimes. Consequently, their existence is evidence in favor of different gas-loss factors, for example, interaction with other small galaxies, gaseous filaments in the intergalactic medium (Benítez-Llambay et al. 2013), or cooling and feedback processes in the early Universe during the epoch of reionization (Bovill & Ricotti 2009). N-body cosmological simulations (e.g., Klypin et al. 1999; Ricotti & Gnedin 2005; Klypin et al. 2014) predict ~ 30 times more massive isolated dwarf galaxies than are actually observed. dSphs with very low surface brightness (LSB) are good candidates for this missing population because they are barely detectable in the optical and radio bands.

In this paper, we report the results of extensive spectroscopic observations carried out with the Russian 6 m telescope. The observed data allowed us to identify neighbors of these three galaxies and estimate group membership distances and physical parameters for them: sizes, masses, and luminosities.

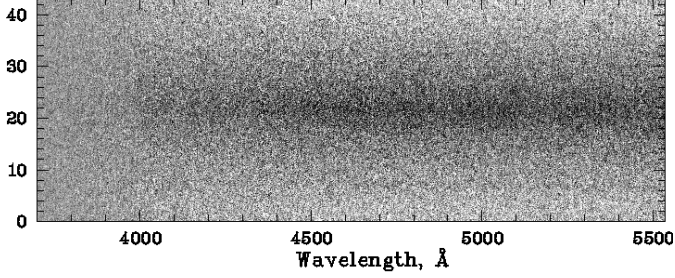
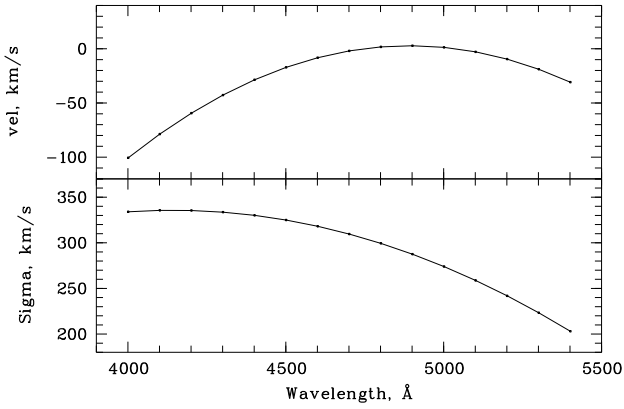
**Table 1.** Main data for the galaxies: (1-2) equatorial coordinates for the epoch J2000.0; (3-6) color excess due to Galactic extinction, galaxy size at the isophote  $SB_V \sim 28$  mag arcsec<sup>-2</sup>, absolute V magnitude and effective radius from our photometry (Sect. 4); group membership distance in Mpc, (8-10) summary of the data acquired from the spectroscopic analysis (Sect. 3): heliocentric radial velocity and its dispersion, and metallicity; (11) radial velocity with respect to the center of the LG calculated according to (Karachentsev & Makarov 1996). The superscripts refer to (1) (Tonry et al. 2001), (2) (Ferrarese et al. 2000), and (3) (Tully & Trentham 2008).

Data/Object	KKH 65	KK 180	KK 227
RA(2000.0)	10 51 59.2	13 04 30.2	13 56 10.1
DEC(2000.0)	+28 21 45	+17 45 32	+40 18 12
$E(B - V)$	0.02	0.02	0.01
Diameter (')	0.94	1.5	0.82
$M_V$ (mag)	-15.08	-14.98	-15.22
$R_{e,V}$ (kpc)	2.40	1.62	2.75
$D_{\odot}^{\text{GrMem}}$ (Mpc)	25.2 <sup>1</sup>	16.4 <sup>2</sup>	29 <sup>3</sup>
$V_h$ (km s <sup>-1</sup> )	1350±50	687±40	2125±65
$\sigma_V$ (km s <sup>-1</sup> )	26:	18:	17:
[Fe/H] (dex)	-1.5 ± 0.3	-1.65 ± 0.52	-0.9 ± 0.4
$V_{LG}$ (km s <sup>-1</sup> )	1301±50	609±40	2186±65

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**Table 2.** Log of spectroscopic observations.

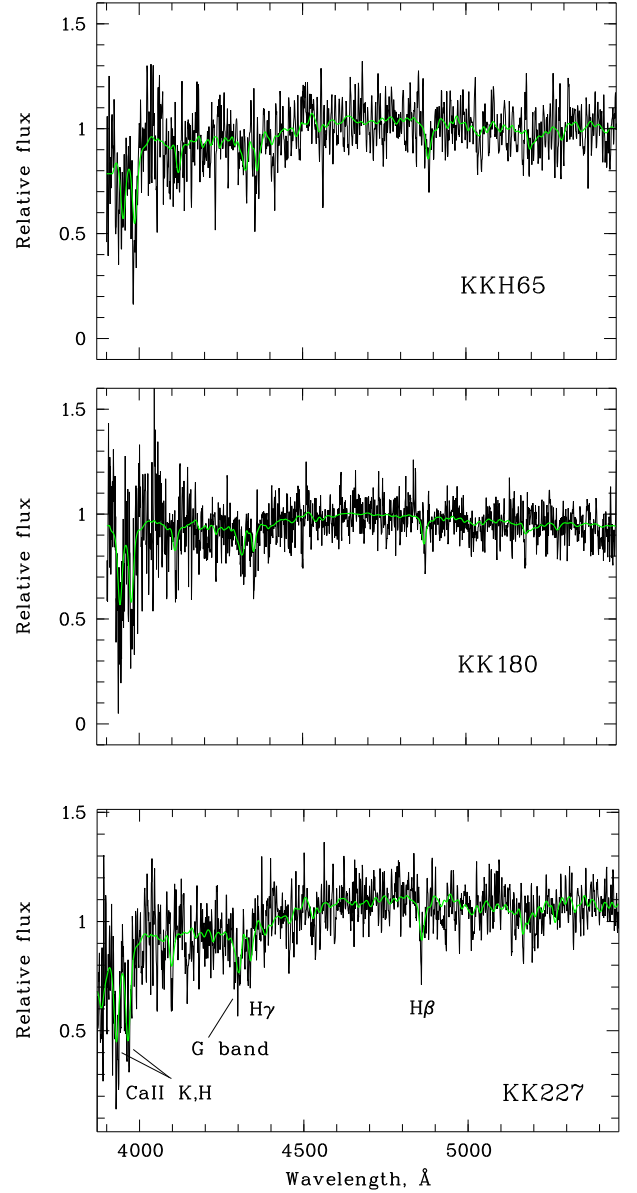
Object	Date (y/m/d)	Exposure (s)	Seeing ( $''$ )
KKH 65	14.02.01	4 x 1200, 1000	2.6
	14.02.03	4 x 1200	1.5
KK 180	14.02.01	4 x 1200	2.6
	14.02.03	2 x 1200, 600	1.5
KK 227	14.02.03	4 x 1200	1.5
	15.02.15	5 x 1200	2.0
	15.02.18	4 x 1200	1.4

**Fig. 1.** One-hour long-slit exposure of KK180, the brightest galaxy of the sample. The vertical axis indicates the position along the slit in arcseconds.**Fig. 2.** Variation of the measured velocity and instrumental velocity dispersion in the twilight spectrum as a function of wavelength.

## 2. Observations and data reduction

Spectroscopic observations were carried out in 2014 and 2015 with the 6-meter telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS). The SCORPIO spectrograph<sup>1</sup> was mounted in the primary focus (Afanasiev & Moiseev 2005). Table 2 includes the date, exposure time, seeing, and heliocentric velocity correction for each galaxy. The atmospheric transparency was very good during the nights. Because of the extremely low brightness of the galaxies (see Fig. 1, Sect. 4), the total exposures for each object were long. The long slit was always  $6' \times 1''$  and the field of view was  $6' \times 6'$ . The instrumental setup included the CCD detector EEV 42-40 with a pixel scale of  $0.18'' \text{ pixel}^{-1}$  and the grism VPHG1200B with a resolution of  $\text{FWHM} \sim 5 \text{ Å}$  and a reciprocal dispersion of  $0.9 \text{ Å/pix}$  in the spectral range of 3700–5500 Å.

<sup>1</sup> <http://www.sao.ru/hq/lon/SCORPIO/scorpio.html>

**Fig. 3.** Integrated spectra of the stellar light of three dSphs (black) (top: KKH 65, middle: KK 180 and bottom: KK 227) in comparison with a composite model (green). The fitting was carried out using the ULySS program, PEGASE-HR SSP model, the ELODIE stellar library, and the LSF of the spectrograph.

Every night, we obtained spectra of twilight, spectrophotometric standard stars, and radial velocity standard stars. The position angle of the slit was always nearly parallactic for all the galaxies except KK 227. Spectra reductions revealed the existence of a faint distant object seen through the stellar body of KK 227 with a spectrum resembling that of a quasi-stellar object (QSO) (see Appendix C). Therefore, this dSph was reobserved in 2015 with a different position of the slit (Fig. C.1) to improve the signal-to-noise ratio in the one-dimensional total spectrum of KK 227.

The standard spectral data reduction was performed using the European Southern Observatory Munich Image Data Analysis System (MIDAS) (Banse et al. 1983) and the Image Reduction and Analysis Facility (IRAF) software system (Tody 1993). The accuracy of the wavelength calibration was  $\sim 0.16 \text{ Å}$ .

### 3. Spectroscopic results

To derive radial velocities of our objects, we used the ULySS package (Koleva et al. 2008, 2009) with the PEGASE-HR model grids (Le Borgne et al. 2004), the Salpeter IMF (Salpeter 1955), and the ELODIE (Prugniel & Soubiran 2001) stellar library. To extract kinematic information from the spectra, we first determined the line spread function (LSF) of our spectrograph using the prescriptions of Koleva et al. (2008). The LSF was approximated by comparing a model spectrum of the Sun with the twilight spectra taken during the same night. The result of the comparison is shown in Fig. 2. It demonstrates the change with wavelength in the measured radial velocity and instrumental velocity dispersion. These dependences were taken into account when we computed radial velocities using ULySS. Figure 3 shows the results of the spectral fitting for the galaxies. One-dimensional total spectra of the galaxies have a quite low signal-to-noise ratio ( $S/N$ ) per pixel in the middle of the spectral range:  $S/N \sim 20$  for KK 180,  $\sim 10$  for KKH 65, and  $\sim 8$  for KK 227. Our spectra allowed us to derive radial velocities, metallicities, and approximate velocity dispersions of KKH 65, KK 180, and KK 227 (Table 1).

### 4. Surface photometry results

We performed surface photometry of the galaxies using Sloan Digital Sky Survey (SDSS) images in the  $g$ ,  $r$ , and  $i$  bands and fitted their surface brightness profiles using the Sersic function (Sersic 1968). The results are shown in Figs. A.2–A.4 and are summarized in Tables 1 (rows 4–6), 3, and A.1. Table 3 contains the following columns: (1) galaxy name, (2) apparent  $V$  magnitude (mag) and mean color ( $V - I$ ), (3) colors ( $B - V$ ) and ( $R - I$ ), (mag), (4) Sersic index  $n$  of the major-axis profile fit in the  $V$  band, (5–7) the corresponding  $V$ -band central SB,  $\mu_{0s}$  in mag arcsec $^{-2}$ , effective radius (arcsec), effective SB in mag arcsec $^{-2}$  and apparent  $V$  magnitude integrated within the effective radius. The photometric data in Table 3 were corrected for Galactic extinction. The procedure of the data analysis is described in Appendix A.

**Table 3.** Surface photometry and Sersic function fitting results for the galaxies.

Name	$V$ $V - I$	$B - V$ $R - I$	$n_V$	$\mu_{e,V}$ $V_e$	$\mu_{V,0}$	$r_{e,V}$
KKH 65	16.93	0.61	0.92	25.97	24.31	19.8
	0.93	0.57	$\pm 0.04$	17.55	$\pm 0.03$	$\pm 0.6$
KK 180	16.09	0.73	0.95	25.38	23.67	20.5
	1.06	0.59	$\pm 0.02$	16.86	$\pm 0.02$	$\pm 0.4$
KK 227	17.09	0.71	0.88	26.06	24.50	19.6
	1.17	0.66	$\pm 0.05$	17.73	$\pm 0.04$	$\pm 0.8$

We estimated the  $K_s$  magnitudes of KKH 65, KK 180, and KK 227 using the transformations between the SDSS and 2MASS photometric systems (Bilir et al. 2011):  $K_{s0} = g - 1.907 \cdot (g - r) - 1.654 \cdot (r - i) - 0.684$ . The  $K_s$  luminosities were converted into stellar masses of the galaxies using  $M_{K_{s0}} = 3.29$  (Blanton & Roweis 2007) and  $(M/L)_{K_s} = 0.9$  in solar units (Maraston 2005).

### 5. Group membership distances of KKH 65, KK 180, and KK 227 and association with other galaxies

Identifying possible neighbors of the three dSphs was an important step of the work. Understanding the real isolation status of the galaxies and their physical properties requires information on their redshift-independent distances. To perform this task, we first searched for possible neighbors within a projected distance of  $\sim 500$  kpc and with differences in radial velocities slower than  $\sim 500$  km s $^{-1}$ . Next, we used the group-finding method by Makarov & Karachentsev (2011, hereafter MK11). The MK11 algorithm uses radial velocities of objects, projected distances between them, and their masses. To apply this method, we used the data obtained in our study for the three dSphs and the corresponding data for the surrounding galaxies extracted from the literature using the Aladin sky atlas (Bonnarel et al. 2000) and the HyperLEDA database (Makarov et al. 2014). We used the value of the Hubble constant:  $H_0 = 73$  km s $^{-1}$  Mpc $^{-1}$ . Appendix B contains the detailed results of group member searches for our galaxies. Tables B.1 and B.2 list the data for the projected neighbors of KKH 65 and KK 180.

### 6. Discussion and conclusions

The estimated metallicities and approximate velocity dispersions (Table 1) of KKH 65, KK 180, and KK 227 are similar of dSphs in the LV (e.g., Gritschneder & Lin 2013). In the following, we examine how typical the other derived parameters are.

**KKH 65.** The nearest bright galaxy to KKH 65 in projection to the sky is the peculiar S0-galaxy NGC 3414. The mean radial velocity of the NGC 3414 group with respect to the LG is  $V_{LG} = 1298 \pm 117$  km s $^{-1}$  (MK11). This value agrees well with the velocity of KKH 65  $V_{LG} = 1301 \pm 50$  km s $^{-1}$  found by us. Thus, KKH 65 is a probable member of the group. We here adopted the distance to the NGC 3414 group measured by Tonry et al. (2001) using SB fluctuations:  $D_{\odot} = 25.2$  Mpc. The corresponding projected separation between KKH 65 and NGC 3414 is 188 kpc, the value typical for dSphs (Karachentsev et al. 2005). At this distance, KKH 65 is larger and more luminous ( $M_V = -15.08$  mag,  $R_{e,V} = 2.4$  kpc) than dSph neighbors of our Galaxy (e.g., McConnachie 2012). The luminous mass of KKH 65 calculated using  $K_{s0} = 15.3$  mag (Sect. 4) is  $9 \times 10^7 M_{\odot}$ .

**KK 180.** The nearest bright galaxy to KK 180 in projection to the sky is the SBc galaxy UGC 8036. Its radial velocity with respect to the LG,  $V_{LG} = 844$  km s $^{-1}$ , is very close to the velocity of KK 180  $V_{LG} = 609 \pm 40$  km s $^{-1}$  that we found. A small galaxy group around UGC 8036 resides in the outskirts of the Virgo cluster (e.g., Tully et al. 2008). We here adopted the distance to KK 180 equal to the distance to the Virgo cluster:  $D_{\odot} = 16.4$  Mpc (Ferrarese et al. 2000). Based on this, KK 180 is located at a projected distance of 1.39 Mpc from M87, that is, within the virial radius of the Virgo cluster  $R_v = 1.8$  Mpc (Hoffman et al. 1980). Its luminosity, effective radius, and mass are  $M_V = -14.98$  mag,  $K_{s0} = 14.14$  mag,  $R_{e,V} = 1.6$  kpc,  $Mass_{K_s} = 1.1 \times 10^8 M_{\odot}$ . KK 180 is as luminous as KKH 65, but by 1.5 times more compact.

**KK 227.** This galaxy most likely belongs to the NGC 5371 group of 55 galaxies (MK11) according to its radial velocity and position in the sky (Table 1). The distance to the Sbc galaxy NGC 5371 was estimated using the Tully-Fisher relation by Tully & Trentham (2008):  $D_{\odot} = 29$  Mpc. The radial velocity of NGC 5371 with respect to the center of the LG is  $V_{LG} = 2640$  km s $^{-1}$  (van Driel et al. 2001). A mean velocity of the group is  $V_{LG} = 2615$  km s $^{-1}$ , and its dispersion is



$\sigma_V = 195 \text{ km s}^{-1}$  (MK11). If we accept the group membership distance  $D_\odot \sim 29 \text{ Mpc}$  for KK 227, then the projected separation between KK 227 and NGC 5371 is  $\sim 74 \text{ kpc}$ ,  $M_V = -15.22 \text{ mag}$ ,  $K_{S_0} = 15.0 \text{ mag}$ ,  $R_{e,V} = 2.75 \text{ kpc}$ , and  $Mass_{K_S} = 1.6 \times 10^8 M_\odot$ .

Colors, metallicities, and surface brightnesses of KH 65, KK 180, and KK 227 are similar to those of dSphs in the Local Group, but the sizes are larger. Objects with similar properties have recently been discovered in the Coma cluster (van Dokkum et al. 2015). Ultra-diffuse galaxies (UDGs) are large objects of extremely low density containing old stellar populations. They are characterized by the following parameters (van Dokkum et al. 2015): effective radii  $R_{eff} = 1.5 - 4.6 \text{ kpc}$ , absolute magnitudes  $-16.0 \leq M_g \leq -12.5$ , central surface brightnesses  $\mu_{g,0} = 24 - 26 \text{ mag arcsec}^{-2}$ , masses  $1 \times 10^7 - 3 \times 10^8 M_\odot$ , and colors  $\langle g - i \rangle = 0.8 \pm 0.1$ . The photometric data, masses, and metallicities of KKH 65 and KK 227 are in an excellent agreement with these values. Therefore, these two dSphs may be classified as UDGs. KK 180 is slightly brighter in the center than typical UDGs.

Our spectroscopic study and grouping analysis allow us to measure radial velocities of KKH 65, KK 180, and KK 227 and derive their group membership distances. We conclude that these three galaxies are non-isolated.

It is worth noting that seven of nine candidates for isolated dSphs from the list of Karachentseva et al. (2010) have been investigated up to now, including our three sample objects. Karachentsev et al. (2014) found out that KK258 is a very isolated transitional-type LSB dwarf galaxy. I.D. Karachentsev measured radial velocity of KKH9 and confirmed it as a probable isolated dSph (private communication). KKR8 was not resolved into stars on the HST images. It is much more distant than has been thought before (L.N. Makarova, private communication, 2015). KKR9 is a Galactic cirrus. Therefore, only two of the seven studied objects are isolated galaxies. In this work we did not expand the list of known isolated dSphs. Objects of this class are extremely rare. More observational efforts are needed to establish the exact frequency of their occurrence in the Local Supercluster.

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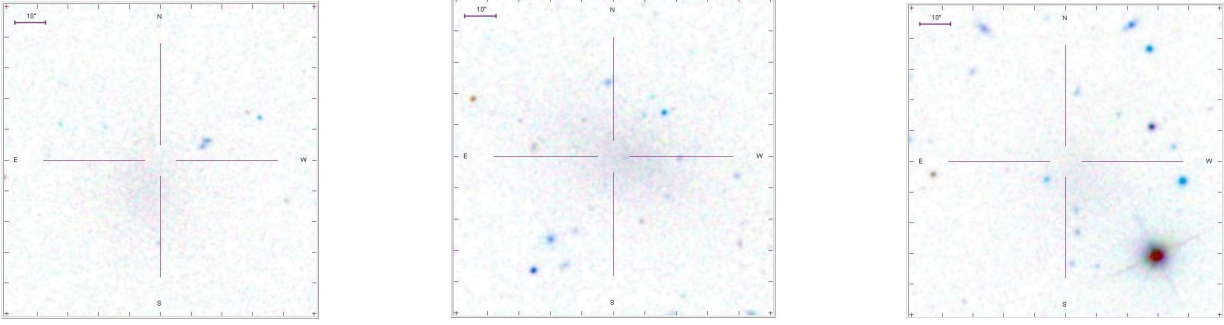
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## Appendix A: SDSS surface photometry of KKH65, KK180, and KK227

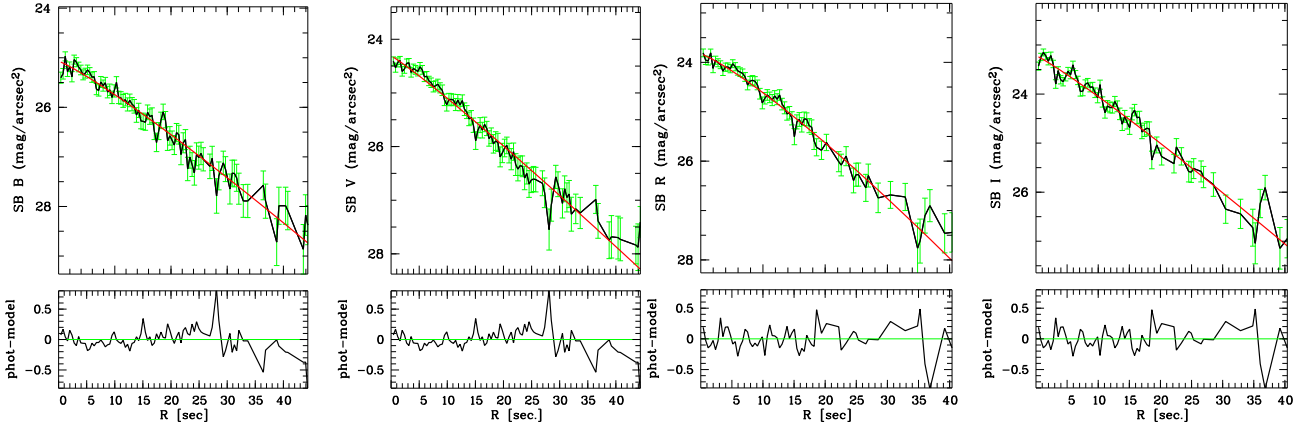
The data reduction<sup>2</sup> and analysis were conducted using the MIDAS package. First, all images were cleaned of all foreground and background objects. Then we used the SURFPHOT program from the MIDAS package to perform all the steps of the photometric procedure: the sky background subtraction, the subsequent ellipse fitting and integration of the light in the obtained ellipses. The algorithm of this software is based on the formulas of Bender (1987) and Bender & Moellenhoff (1987). The FIT/FLAT\_SKY task was used to approximate the sky background by a surface created with a two-dimensional polynomial and the least-squares method. All pixels of the residual image with values that differed by more than two sigma from the mean value of the sky were not used in the calculation of the background level with the FIT/BACKGROUND program. The typical accuracy of the sky brightness estimation was better than 1 %. This corresponds to the level  $SB \sim 27\text{--}28 \text{ mag arcsec}^{-2}$  in the B band. The ellipse fitting was carried out using the sky-subtracted images and the task FIT/ELL3. The INTEGRATE/ELLIPSE program was used to integrate the light in the successive ellipses. To transform SDSS magnitudes into the Johnson-Cousins system, we used the empirical color transformations by Jordi et al. (2006).



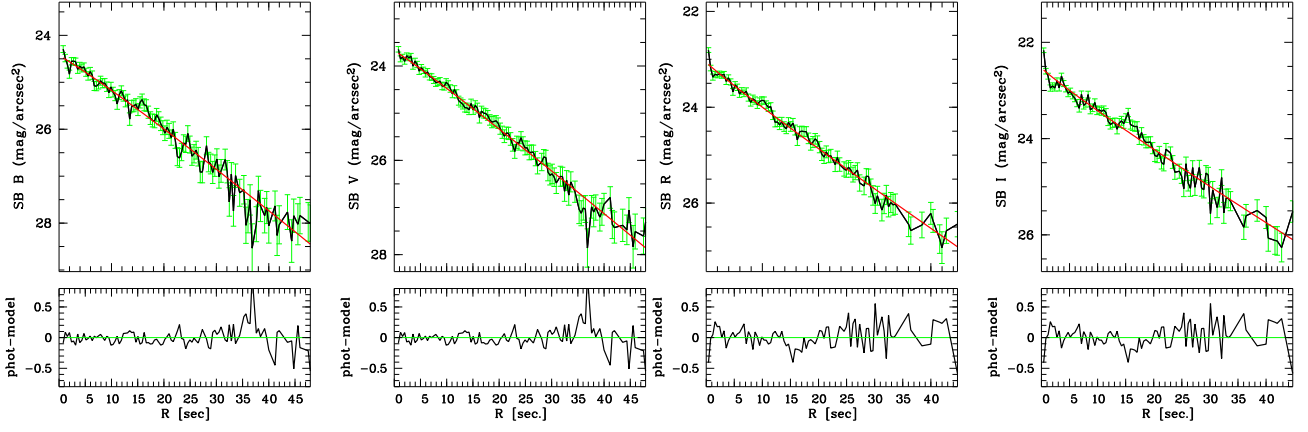
**Fig. A.1.** SDSS images of the three dSphs KKH 65, KK 180, and KK 227 (from left to right).

**Table A.1.** Surface photometry using SDSS images in the g, r, i bands and Sersic function fitting results for KKH 65, KK 180, and KK 227. The columns represent the following data: (1) galaxy name, (2) limiting radius of our photometry in arcmin and axes ratio, (3) integrated magnitude within the limiting diameter, (4) total Sersic model magnitude, (5) integrated magnitude within the isophote  $25 \text{ mag arcsec}^{-2}$ , (6) mean surface brightness within the isophote  $25 \text{ mag arcsec}^{-2}$ , (7) Sersic index  $n$  of the major-axis profile fit, (8-10) corresponding Sersic model central surface brightness, effective radius in arcsec, and effective surface brightness, and (9) integrated magnitude within the effective radius.

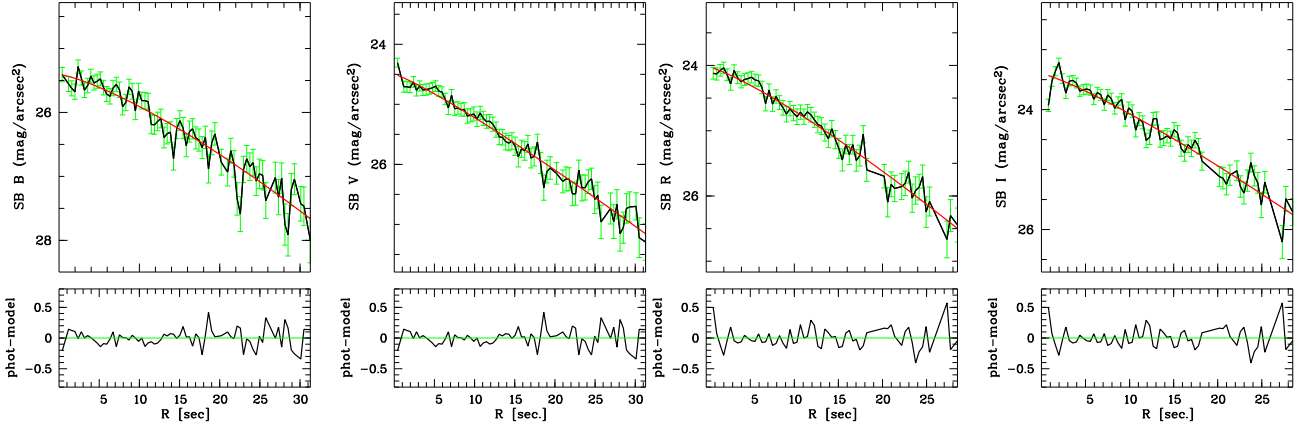
Name	$R_{lim}$ $b/a$	$g_t$ $r_t$ $i_t$	$g_t$ $r_t$ $i_t$	$g_{25}$ $r_{25}$ $i_{25}$	$n_{gs}$ $n_{rs}$ $n_{is}$	$\mu_{g,0s}$ $\mu_{r,0s}$ $\mu_{i,0s}$	$r_{e,gs}$ $r_{e,rs}$ $r_{e,is}$	$\mu_{e,gs}$ $\mu_{e,rs}$ $\mu_{e,is}$	$g_e$ $r_e$ $i_e$
(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)
KKH 65	0.67	17.14	17.05	19.60	$0.88 \pm 0.03$	$24.69 \pm 0.02$	$20.52 \pm 0.42$	26.25	17.79
	0.70	16.83	16.82	17.88	$0.77 \pm 0.02$	$24.11 \pm 0.02$	$16.22 \pm 0.31$	25.45	17.58
		16.57	16.43	17.19	$0.85 \pm 0.02$	$23.72 \pm 0.02$	$17.21 \pm 0.35$	25.23	17.15
KK 180	0.75	16.52	16.42	17.89	$0.97 \pm 0.02$	$23.96 \pm 0.02$	$21.06 \pm 0.29$	25.71	17.13
	0.71	16.02	15.89	16.66	$0.98 \pm 0.02$	$23.36 \pm 0.02$	$20.58 \pm 0.35$	25.15	16.63
		15.58	15.52	16.10	$0.94 \pm 0.02$	$23.14 \pm 0.02$	$21.27 \pm 0.40$	24.82	16.23
KK 227	0.48	17.49	17.22	—	$0.76 \pm 0.03$	$24.99 \pm 0.02$	$20.00 \pm 0.50$	26.29	18.00
	0.81	17.10	16.85	18.05	$0.82 \pm 0.03$	$24.24 \pm 0.03$	$17.51 \pm 0.51$	25.66	17.57
		16.62	16.34	17.35	$0.84 \pm 0.03$	$23.88 \pm 0.02$	$19.15 \pm 0.54$	25.37	17.12



**Fig. A.2.** Sersic function fits to the equivalent profiles of KKH 65 in the *B*, *V*, *R*, *I* bands.



**Fig. A.3.** Same as Fig. A.2, but for KK 180.



**Fig. A.4.** Same as Fig. A.3, but for KK 227.

## Appendix B: Members of the groups containing KKH 65 and KK180

### B.1. NGC 3414 group

The algorithm developed by MK11 identified eight members of the NGC 3414 group. Using the same group-finding algorithm and new observational data (radial velocities from SDSS DR9 and spectroscopic and photometric data for KKH 65), we found 19 galaxies with differences in radial velocities  $|V_{LG}^{N3414} - V_{LG}^{gal}|$  smaller than  $600 \text{ km s}^{-1}$  and within the projected radius from NGC3414  $R_{N3414}^{proj} = 600 \text{ kpc}$  (Table B.1). Eleven of them are members of the group with  $ii < 1$ , and eight objects are candidate field galaxies with  $ii > 1$ . Some of  $\log(ii)$  values are close to zero. This means that the actual group size may change if accurate redshift-independent distances will be available. After selecting the group members, we compared the properties of KKH 65 and the surrounding galaxies. There are three candidate early-type group member galaxies fainter than KKH 65, and six candidate field early-type objects comparable to KKH 65 (Table B.1). SDSS images and our photometric study indicate that KKH 65 is the most diffuse among all these objects.

Table B.1 lists the data for the projected neighbors of KKH 65 with the differences in radial velocities between NGC 3414 and each individual galaxy that are smaller than  $600 \text{ km s}^{-1}$ : (1) galaxy name, (2) equatorial coordinates, (3) morphological type in numerical code according to the RC3 catalog (de Vaucouleurs et al. 1991), (4) integrated magnitude in the  $Ks$  band, corrected for Galactic extinction, (5) radial velocity with respect to the centroid of the LG, (6) projected separation in kpc from NGC3414 assuming that the galaxies are located at their Hubble distances, (7) logarithmic isolation index calculated with respect to NGC 3414 calculated according to MK11.

**Table B.1.** S0 galaxy NGC3414 and galaxies with differences in radial velocities  $|V_{LG}^{N3414} - V_{LG}^{gal}|$  smaller than  $600 \text{ km s}^{-1}$  and within the projected radius from NGC3414  $R_{N3414}^{proj} = 600 \text{ kpc}$ .

Galaxy	RA (J2000.0) DEC	T	$K_{s0}$	$V_{LG}$	$R_{N3414}^{proj}$	$\log(ii)$
	<i>h m s</i> <i>° ' "</i>		(mag)	(km/s)	(kpc)	(N3414)
NGC3414	10 51 16.21 +27 58 30.4	-2	8.03	1351	0	
UGC5844	10 43 55.98 +28 08 50.1	7	13.9	1398	535	-0.32
UGC5921	10 49 12.79 +27 55 21.3	8	13.48	1356	148	-2.23
NGC3400	10 50 45.47 +28 28 08.6	1	10.20	1344	163	-2.16
PGC4576692	10 50 49.39 +28 03 30.6	9	16.5	1460	43	-0.69
PGC1823017	10 51 07.88 +27 58 46.5	-1	18.0	1779	12	-0.06
[KK90]013, PGC93597	10 51 13.01 +28 00 22.3	-3	12.38	1125	10	-0.66
UGC5958	10 51 15.87 +27 50 55.6	4	12.4	1113	37	-0.04
SDSS J105123.21+280125.7	10 51 23.21 +28 01 25.7	-3	15.8	1646	20	-0.15
NGC3418	10 51 23.95 +28 06 43.2	0	10.38	1187	42	-0.34
BTS22	10 51 37.14 +27 49 19.6	-3	14.4	1256	53	-0.67
<b>KKH 65=BTS23</b>	10 51 59.00 +28 21 45.0	-3	15.3	1282	132	-0.58
PGC4251293	10 46 30.44 +27 41 56.2	10	15.5	1468	367	0.31
NGC3380	10 48 12.17 +28 36 06.4	1	9.99	1528	317	0.53
PGC4558491	10 50 13.88 +27 18 03.9	-3	16.0	1604	252	0.82
BTS24	10 52 00.35 +27 45 32.7	-2	15.6	1591	95	0.29
PGC1813510	10 52 14.12 +27 37 23.8	-1	15.2	1511	141	0.16
SDSS J105218.32+272314.2	10 52 18.32 +27 23 14.2	10	15.9	1595	222	0.79
NGC 3451	10 54 20.97 +27 14 25.1	7	10.2	1259	313	0.04
PGC4572094	10 54 41.75 +28 07 31.1	9	15.9	1537	266	0.57

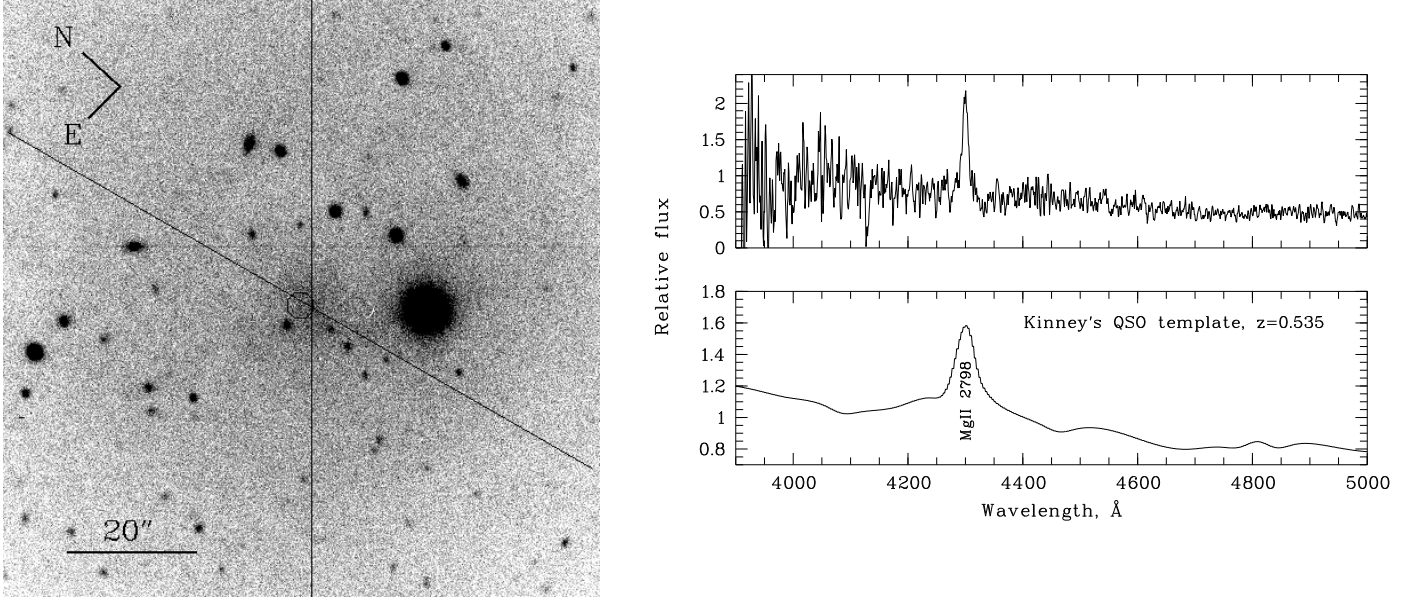
### B.2. UGC8036 group

Table B.2 lists galaxies located within the projected vicinity from KK 180. The results of the MK11 algorithm (Table B.2) favor an extremely weak gravitational influence between the UGC 8036 group members. At the same time, the gravitational attraction from the Virgo cluster is strong. (1) Galaxy name, (2) equatorial coordinates, (3) morphological type in numerical code according to de Vaucouleurs et al. (1991), (4) integrated magnitude in the  $Ks$  band, (5) radial velocity with respect to the centroid of the LG, (8) projected separation in kpc from UGC 8036, (9) isolation index with respect to UGC 8036, (10) projected separation in Mpc from M87, (11) isolation index calculated with respect to the center of the Virgo cluster with the total mass of  $8 \times 10^{14} M_{\odot}$  (Karachentsev et al. 2014). The projected separations are calculated assuming that the galaxies are at their Hubble distances.

**Table B.2.** Most massive galaxy in the Virgo cluster M87 and six galaxies around KK180 with a radial velocity difference smaller than  $|V_{LG}^{M87} - V_{LG}^{gal}| < 600 \text{ km s}^{-1}$  and within the projected radius from KK180  $R_{KK180}^{proj} = 600 \text{ kpc}$ .

Galaxy	RA (J2000.0) DEC						T	$Ks_0$	$V_{LG}$	$R_{U8036}^{proj}$	$\log(ii)$	$R_{VC}^{proj}$	$\log(ii)$
	<i>h</i>	<i>m</i>	<i>s</i>	<i>°</i>	<i>'</i>	<i>''</i>		mag	km/s	Mpc	U8036	Mpc	VC
NGC4486=M87	12	30	49.41	+12	23	28.5	-4	5.4	1165	–	–	0.00	–
UGC8036	12	54	48.60	+19	10	37.6	6	11.96	844	0.00	–	1.27	-1.57
SDSS J125651.47+163024.2	12	56	51.50	+16	30	24.2	-2	13.39	1157	0.60	3.30	1.07	-1.26
[KK98] 173, LSBC D575-07	12	58	35.97	+17	48	46.9	9	18.70	934	0.35	2.08	1.23	-1.83
SDSS J130320.36+175909.7	13	03	20.43	+17	59	09.1	-2	15.28	926	0.50	2.13	1.38	-1.75
<b>KK 180</b>	13	04	30.00	+17	45	32.0	-3	14.14	609	0.47	3.01	1.39	-1.20
SDSS J130440.05+184438.7	13	04	40.05	+18	44	39.1	10	15.71	766	0.46	2.06	1.48	-1.36





**Fig. C.1.** Left: Settings of the slit on the preliminary short-exposure image of KK 227 in the *B* band. The approximate location of a quasar is circled. Right: One-dimensional total spectrum of the quasar after observations in the two positions of the slit.

### Appendix C: QSO projected on KK 227

The long-slit observations revealed a distant extended object seen through the stellar body of KK 227 with a QSO-like spectrum. It was detected in both slit positions. We estimated its redshift  $z = 0.535$  using only one clearly seen line MgII 2798Å. The orientation of the slit in the case of KK 227 and the location of the quasar are shown in Fig. C.1.